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Semi-annual review of MODIS science team activity of Yoram Kaufman
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1. Remote sensing of aerosol over the land and atmospheric corrections

Identification of major research issues:

* The 3.75 µm channel vs.. the 2.15 µm channel.

The main methods for remote sensing of aerosol over the land are based on identification of surface features that are dark enough (reflectance less than 0.05) and repetitive at some spectral channels. This is difficult in the presence of aerosol that increases the apparent reflectance and thus brightens the dark pixels. Previous research showed that radiance in the 3.75 µm channel can be used to identify the dark pixels, since it is not sensitive to the presence of aerosol (except of dust) and is sensitive to the same properties of the surface that determine their reflectance in the red and blue channels. Therefore, the 3.75 µm channel can be used to identify pixels that are dark in the red and blue channels even in the presence of aerosol. Unfortunately several disadvantages were detected in this channel. It is more sensitive to the presence of liquid water in soils and vegetation than the visible channels and thus the relationship between the 3.75 µm channel and the visible channels may vary. This channel also requires correction for thermal emission, that in turn requires an assumption of a value of the emissivity in the 11 µm channel. Therefore, although the 3.75 channel is predicted to be very useful for aerosol remote sensing, the question arises if the 2.15 µm channel, the longest channel that is not affected by thermal emission, can be used to identify pixels with surface cover that is dark in the red and blue channels.

* Sensitivity studies and validation.

By the time MODIS flies on EOS-A, we need to know in which geographical regions we can apply specific algorithms for remote sensing of aerosol over the land and with what accuracy. Before the deadline for algorithm delivery we shall not be able to validate the algorithms for all the possible surface covers and aerosol types using field data. Therefore, the answers have to come from sensitivity studies. The input to the sensitivity studies are the surface spectral and angular reflectance and the aerosol optical properties. The sensitivity studies will be performed using the radiative transfer theory. In order to obtain reliable results from the sensitivity study, two conditions have to be met:

- We need a data set of the surface spectral and angular reflectance properties that represent as close as possible the different conditions that MODIS will observe over the world.

- We need a data set of the optical properties of the aerosol particles. Since aerosol models assume that aerosol particles are homogeneous and spherical, there is a need to perform measurements that will determine the validity of these assumptions.

Accomplishments and on going research

* The 3.75 μm channel.

Work continues on the relationship between the surface properties in the 3.75 μm channel and the 0.64 μm channel using AVHRR data over the Eastern US and over Brazil. A paper is in preparation, with Lorraine Remer, showing a strong relation between the reflectance in the two channels in a given image. However, the relationship in the summer was shown to be different from that in the spring. It is possible that greening of trees reduces the reflectance in the 0.64 μm channel more than in the 3.75 μm. It is also possible that the surface emissivity at 11 μm varies with season and thus creates an error in the emission correction. A sensitivity study, using surface reflectance measured from the AVHRR, for a few aerosol models shows that, as expected, the apparent reflectance in the 3.75 μm is not sensitive to the aerosol loading, while that in the 0.64 μm channel is.

* Vegetation indexes

As a by-product of the research regarding the properties of the 3.75 μm channel to determine dark pixels that can be used to detect aerosol, we analyzed AVHRR data, for a vegetation index that uses the reflective part of the 3.75 μm channel instead of the red channel:

$$NDVI=(L_{0.86} - L_{0.64})/(L_{0.86} + L_{0.64}) \implies VI3=(L_{0.86} - L_{3.75r})/(L_{0.86} + L_{3.75r})$$

where $L_{0.86}$ and $L_{0.64}$ are the normalized radiances (normalized to reflectance units at 0.86 and 0.64 μm and $L_{3.75r}$ is the reflective part of the 3.75 μm channel. The results show that the new index, VI3, correlates very well with the NDVI in the absence of heavy aerosol or variation in the precipitable water vapor. Since the index does not include the red channel that suffers from atmospheric effects, the resulting index was shown in a sensitivity study not to be affected by variations in the aerosol loading. Note that the aerosol effect on the near IR channel is small, due to the high values of the surface reflectance, and the effect of water vapor on $L_{0.86}$ and $L_{3.75r}$ are very similar and cancel out in VI3.

* Surface reflectance data set.

A new effort was initiated to collect data sets of the surface properties. We have in mind to represent the variability of surface properties. The spectral variability is the most important, followed by angular variability, and by spatial variability. The main emphasize is on the AVIRIS data that covers the entire solar spectrum (0.4-2.5 μm) for nadir view. This data set is supplemented by spectra taken from the literature. Bo-Cai Gao contacted several institutes that generated interesting data sets. Most of them are from laboratory measurements, and therefore may not represent exactly the natural conditions, but be a good basis to increase the statistics of the natural relation that can be obtained from the AVIRIS. A data set that cover the IR region (2-14 μm) was obtain from John Salisbury at Johns Hopkins University. This data set can serve to relate the surface properties in the 3.75 and 11 μm channels, important for the emission correction.

Work also continues on analysis of data from quantitative photography in a green terrain (a region adjacent to Wallops) and in a desert transition zone in Israel. The data are in 4 broad spectral bands in the solar spectrum but the high spatial resolution and the range of view directions ±30° makes it appropriate for studies in these two dimensions. We plan to analyze the reflectance properties of mixed surfaces (soil and vegetation) as a function of the fraction of the pixel covered by vegetation, with the proper influence of shadowing in the image. We will try to use LANDSAT TM data as well as the ASAS aircraft data to enhance the angular and spatial representativenes of the data set.

* Aerosol properties.

An effort was initiated to measure the physical and optical properties of aerosol particles. A data set of ground based measurements from the last 3 years of the spectral transmission of sunlight and of the sky almucantar brightness is being analyzed. The data set was collected at different locations around the world: desert transition zone, heavy polluted areas (East Europe, Italy), Tropical area (Brazil), mixed aerosol (California). Even though the measurements are taken from ground, the measurements represent not only the particles size distribution (for radius of 0.08-8 μm), but also the actual scattering phase function at scattering angle of 120°. This is the same scattering phase function that determines the path radiance that influence satellite imagery. The analysis show that although in average Mie computations of the scattering phase function for homogeneous spherical particles do represent the actual average phase function, in specific location there may be variations of 20-30% between the actual phase function and the computed one.

We anticipate to expand substantially this activity in the future through a network of instruments in Brazil (by a separately funded study of Brent Holben) and in Africa (by Didier Tanré). A network of instruments was purchased by us to serve as a movable network to support field experiments and to take measurements in locations that supply information on aerosol types not covered otherwise.

2. Remote sensing of cirrus clouds

The proposal of Bo-Cai Gao to replace one of the MODIS channels into the 1.38 μm channel was accepted. This was an exciting collaboration with other science team members and mainly the atmospheric team. This channel is located in a very strong water vapor absorption band. As a result the lowest 6 km of the atmosphere are completely absorbing. As a result the presence of cirrus can be observed on a black background, even over a reflective earth surface. Cirrus clouds have a profound climatic greenhouse effect, and therefore are expected to have a major role in a possible climate change. Cirrus clouds also contaminate imagery used to observe surface properties and properties of the lower atmosphere. Therefore detailed detection of cirrus clouds should have a profound effect on most algorithms derived from the MODIS data. Several studies are planed by Bo-Cai Gao and others as a part of this investigation as well as by support of other research activities. We shall have to establish the collaboration with other members of the atmospheric team and the MODIS cloud screening activity regarding continued activity using this channel.

3. Field experiments - SCAR

Except of the sunphotometry networks that are planned to collect information on the physical and optical properties of aerosol, the main field activity is planned in the context of the SCAR experiment. SCAR stands for "Smoke Clouds And Radiation", but it will cover surface properties as well, and will start July, 1993 in the Eastern US with measurements of the properties of the earth surface, the atmospheric aerosol (mainly sulfates in this region) and of cloud properties, detecting radiation from 0.5 μm to 14 μm. The remote sensing measurements will include also a water vapor channel. The main remote sensing instrument will be the MODIS simulator (MAS). Since the MODIS simulator does not cover all the interesting MODIS channels, and since it is a new instrument, we shall try to fly MAS as much as possible simultaneously with observations from the AVIRIS instrument. Measurements are also planned of the total upward flux and of the atmospheric profiles using a lidar system. In addition to collecting first data over the continents with the MAS, the 1993 SCAR experiment should be a prelude to the 1994 Brazilian experiment. NASA HQR is suppose to draw an international agreement for this purpose with INPE Brazil, and to invite some of the Brazilian scientists to the 1993 experiment. In 1994 (August-Sept.) we plan to bring the ER-2 to Brazilian as a joint venture among several MODIS science team members. In parallel we collaborate with Peter Hobbs from U. of Washington that will bring his flying laboratory to Brazil to measure in situ trace gases, aerosol and cloud properties as well as remote sensing measurements using the CAR radiometer of Mike King and a lidar. A combination of these two instrumented airplanes and ground support (including the network of Brent Holben) will generate an outstanding capability to measure the properties of vegetation, smoke aerosol and clouds, both in situ and from remote sensing. We hope to learn from this experiment the characteristics of smoke and tropical clouds in the dry season, the effect of smoke on clouds and climate, and the ability of a sensor similar to MODIS to sense correctly these physical parameters. This activity is in accord with NASA and international interest in the effect of aerosol particles on climate. Peter Hobbs organizes the International Global Aerosol Project (IGAP). This IAMAP-WMO project includes 6 sub-projects, including the biomass burning aerosol of which Yoram Kaufman will serve as the chair. The activity of this project is expected to concentrate on the smoke aerosol in the Amazon basin (AEROZON).

4. Problems

* We are not sure if there is any progress regarding the preparation in NASA HQR for the SCAR experiment. We anticipate the initiation of an international agreement and invitation of Brazilian collaborators for the 1993 experiment.

* We shall increase the collaboration with the MODIS technical team and the land team regarding the development of the data sets for representing surface properties.